

The University of Chicago

THE EFFECT OF INDUCED MUS-
CULAR TENSION UPON VARIOUS
PHASES OF THE LEARNING
PROCESS

A PART OF A DISSERTATION SUBMITTED TO
THE FACULTY OF THE DIVISION OF THE
BIOLOGICAL SCIENCES IN CANDIDACY FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

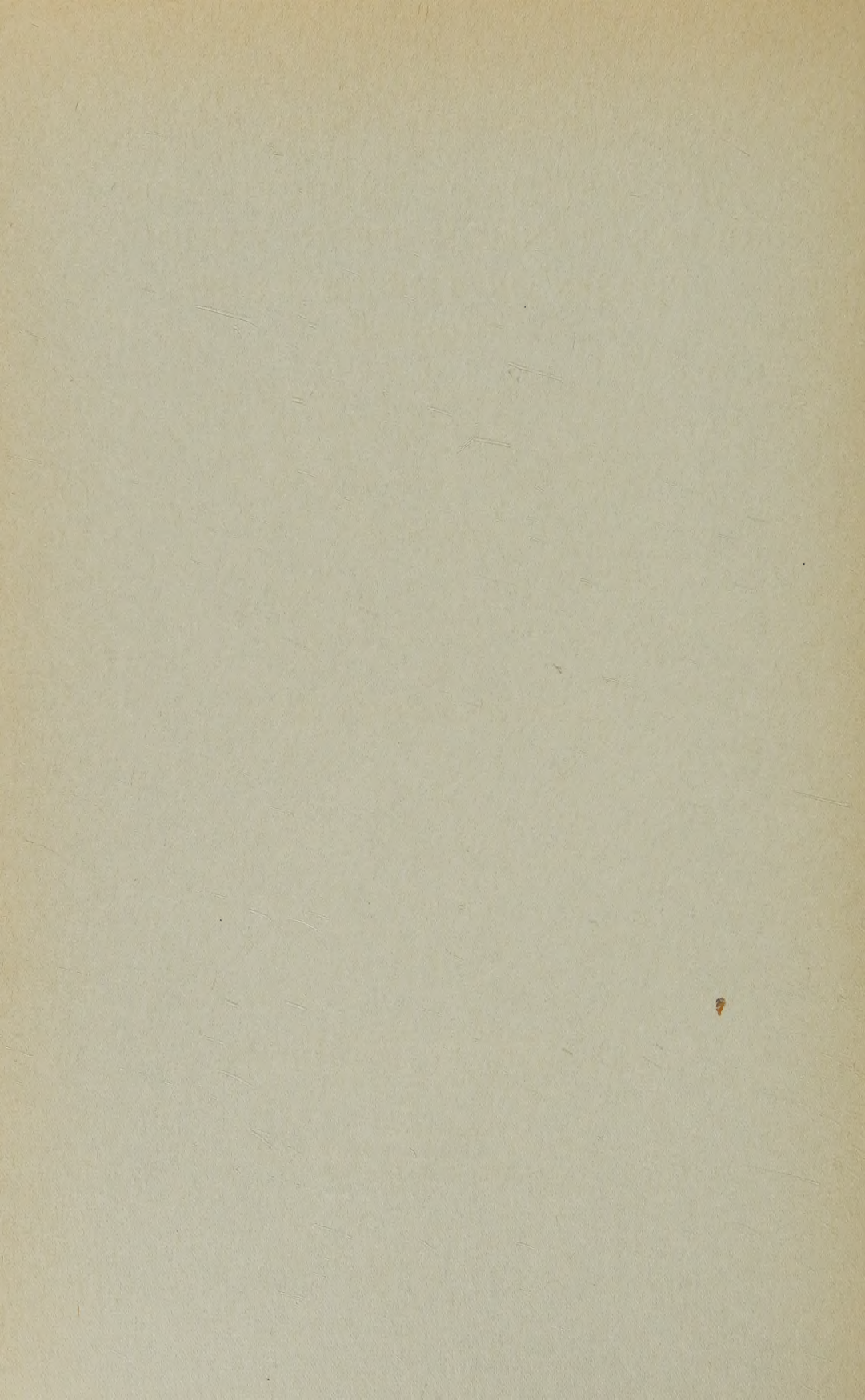
DEPARTMENT OF PSYCHOLOGY

1936

By
JAMES C. STAUFFACHER

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THE EFFECT OF INDUCED MUSCULAR TENSION UPON VARIOUS PHASES OF THE LEARNING PROCESS

BY JAMES C. STAUFFACHER *

INTRODUCTION

Although a great deal of research has been reported on the interdependence of various mental activities and the motor processes, a relatively small amount of work has been reported on the inter-relationship between learning and muscular tension. Investigations which have been done upon this problem may be divided into two main sorts of inquiries: (1) What is the effect of learning upon muscular tonicity? (2) What is the effect of changes in muscular tension upon the efficiency of learning?

Prominent among studies following the first line of inquiry are the following. McTeer (11) found that punishment in the form of an electric shock tended to produce greater tension in the inactive hand during the course of mirror drawing activity. Clites (5) used the three water-dipping problems found at the superior adult level of the Binet test and found an increase in the winking rate accompanying this type of activity. Book (4) found that when a subject learning to typewrite made a special effort to overcome errors, he used extra force in hitting the keys. Stroud (14) found a correlation between the speed of learning and the amount of tension as measured by the pressure on the stylus in human maze learning. Ghisseli (9) worked with two multiple choice visual motor speed tasks and found that tension was maintained at a constant level during learning and that once the task was learned the tension markedly decreased.

The other line of approach used in studying the interdependence of learning and muscular tonicity consists of changing the degree of muscle tension and noting the change

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in efficiency of learning. For example, Reed (13) reported that learning scores were affected by the posture assumed at the time of learning (sitting being more advantageous than standing) but that recall was not affected by a shift in posture at the time of recall. Since the sitting position is the more customarily assumed during work of this type, the influence of habit would probably give this effect regardless of the muscular tensions involved. On the other hand, Bills (1) induced muscular tension by the use of the hand dynamometer and found that the efficiency of learning was increased. Stroud (14) reported that the rate of learning the stylus maze was materially increased when muscular tension was artificially induced in the hands of the subject.

The results of these experiments indicate in general that there is a correlation between a certain degree of muscular tension and efficiency of learning. This conclusion clears the way for further studies of the effects of muscular tension. The study here reported deals with the investigation of several of these problems.

- I. What is the effect of varying degrees of induced muscular tension upon the rate of learning?
- II. What is the effect of muscular tension induced during the original learning upon retroactive interference?
- III. What is the effect of induced muscular tension introduced during relearning upon the efficiency of recall and relearning?

EXPERIMENT I

The Degree of Induced Muscular Tension and the Rate of Learning

Problem.—Several studies have shown that a certain amount of induced muscular tension is facilitative to learning. These conclusions would lead one to think that perhaps different degrees of induced tension introduced during learning might produce different effects upon the efficiency of that process. This experiment is an investigation of this problem. Stated in other words the question reads, "Is there a certain degree of tension which will give a maximum amount of

facilitation in learning and if so, approximately how much is this?"

Apparatus.—Tension was induced by weights suspended over pulleys which were attached to the far side of a table. The amount of tension could be accurately varied by combining the various weights. The subjects gripped the stirrup-handles, lifted the weights off the floor and supported them. This procedure was successful in minimizing the distraction, since no effort or attention was required from the subject in order to keep the induced tension constant. In using the heavier of the weights, it was found necessary to screw the table securely to the floor, to insure its stability.

An electrically driven memory drum which advanced every two seconds was used to expose the material to be learned. This material consisted of four lists of fifteen, three letter nonsense syllables.

Auxiliary handles were attached to the movable arms of two Smedley spring dynamometers which were clamped securely to the top of the table. The subject could then pull on these in the same manner that they were required to do in order to support the weights. This device was used to measure the relative strength of the subjects.

Subjects.—Forty graduate and undergraduate students in the Department of Psychology served as subjects in this experiment.

Procedure.—A preliminary test was given each subject in order that the amount of weight used for the induction of tonus could be made proportional to the strength of the individual. The subjects were instructed to exert their maximum pull on the two auxiliary handles of the dynamometers for one minute. The strength of the pull at the end of this period was taken as the maximum pull. The work was carried on under four conditions: (1) No induced tension, (2) One-quarter of the total tested pull, (3) One-half of the total tested, and (4) Three-quarters of the total tested. Every subject worked under all four conditions, one condition on each day (usually consecutive). The order of the various conditions (*A*, *B*, *C*, and *D*) and the syllable lists used (1, 2, 3, and 4) were systematically varied from subject to subject, in order to counterbalance practice and the relation of list to condition as shown in Table I.

The instructions to the subjects were as follows: "I have placed a list of fifteen, three letter nonsense syllables on this revolving drum. [The nature of these syllables

TABLE I
ORDER OF CONDITIONS AND LISTS USED IN EXPERIMENT I

Subject	First Day	Second Day	Third Day	Fourth Day
1	<i>A</i> (1)	<i>B</i> (2)	<i>C</i> (3)	<i>D</i> (4)
2	<i>B</i> (1)	<i>C</i> (2)	<i>D</i> (3)	<i>A</i> (4)
3	<i>C</i> (1)	<i>D</i> (2)	<i>A</i> (3)	<i>B</i> (4)
4	<i>D</i> (1)	<i>A</i> (2)	<i>B</i> (3)	<i>C</i> (4)
5	Same as subject 1.			
etc.				

was explained to any subjects not familiar with them.] The drum revolves intermittently, so that each syllable appears in the window for two seconds. I want you to learn as many of the syllables as you can. Learn as many as possible on the first revolution of the drum and when the XX's appear, you are to spell out the first syllable. When the first syllable appears, try to spell the second one and so on through the list, each syllable acting as the stimulus for you to spell the one that follows. You will be given six trials and you are to spell as many as possible on each trial after the first."

The instructions for the tonus conditions were: "I want you to support these weights while you are learning. Grasp the handles and pull until your elbows are even with the side of your body." A demonstration was given if the subject did not understand what was expected of him.

Results.—Two criteria were used in measuring the efficiency of the learning under the various conditions of muscle tension. First, a comparison was made of the number of syllables correctly spelled on the last trial under the four different conditions. This is shown in Table II. Condition

TABLE II
THE EFFECT OF DEGREE OF TENSION UPON THE NUMBER OF SYLLABLES ANTICIPATED
CORRECTLY ON THE LAST TRIAL (AVERAGES FOR FORTY SUBJECTS)

Condition	Amount of Induced Tension	Average No. of Syllables Anticipated Correctly on Last Trial	
<i>A</i>	0	4.8 ± 0.25	
<i>B</i>	$\frac{1}{4}$ total tested	5.3 ± 0.22	
<i>C</i>	$\frac{1}{2}$ total tested	5.6 ± 0.25	
<i>D</i>	$\frac{3}{4}$ total tested	5.3 ± 0.26	

Conditions	R.O. Correl.	Difference	Difference P.E. Diff.
<i>A</i> and <i>B</i>	.478	.5 ± 0.24	2.1
<i>A</i> and <i>C</i>	.648	.8 ± 0.19	4.4
<i>A</i> and <i>D</i>	.511	.5 ± 0.25	2.0
<i>B</i> and <i>C</i>	.665	.3 ± 0.19	1.7
<i>B</i> and <i>D</i>	.693	0	—
<i>C</i> and <i>D</i>	.631	.3 ± 0.22	1.4

C differed most from Condition *A* (the normal condition), the difference being .8 ± .19. This difference was 4.4 times its P.E. It will be remembered that Condition *C* is that condition where the tension is one-half the maximum tested load. All conditions of induced tension used, however, were slightly facilitative when compared with the condition of normal tension. These differences are only about two times their P.E.'s and are of questionable reliability.

A comparison was also made of the most syllables anticipated correctly on any one trial under the four conditions as shown in Table III. The use of this criterion was suggested by the observed fact that a subject might name very few or even no syllables on a given trial due to his having gotten a poor start or for other reasons. If this happened on the last trial, then the number anticipated during this trial would be a poor criterion of the amount of learning accomplished. The use of the most number of syllables correctly anticipated on any one trial does not depend upon performance during any given trial and so is not subject to this criticism. Again

TABLE III
THE EFFECT OF DEGREE OF TENSION UPON THE LARGEST NUMBER OF SYLLABLES
ANTICIPATED CORRECTLY ON ANY ONE TRIAL (AVERAGES
FOR FORTY SUBJECTS)

Condition	Amount of Induced Tension	Average No. of Syllables Anticipated Correctly on All Trials	
<i>A</i>	0	5.2 ± 0.23	
<i>B</i>	$\frac{1}{4}$ total tested	5.6 ± 0.21	
<i>C</i>	$\frac{1}{2}$ total tested	6.3 ± 0.23	
<i>D</i>	$\frac{3}{4}$ total tested	5.4 ± 0.25	

Conditions	R.O. Correl.	Difference	Difference P.E. Diff.
<i>A</i> and <i>B</i>	.477	$.4 \pm 0.23$	1.7
<i>A</i> and <i>C</i>	.629	1.1 ± 0.19	5.8
<i>A</i> and <i>D</i>	.557	$.2 \pm 0.23$	.9
<i>B</i> and <i>C</i>	.633	$.7 \pm 0.18$	3.9
<i>B</i> and <i>D</i>	.682	$.2 \pm 0.19$	.1
<i>C</i> and <i>D</i>	.697	$.9 \pm 0.18$	5.0

Condition *C* showed the greatest difference from the normal condition, this difference being 1.1 ± 0.19 (5.8 times it's P.E.). The other tension conditions were also slightly facilitative when this criterion was used.

An attempt was made to compare the performance of the best and the poorest learners under the four conditions of muscle tension. The individuals selected did not divide themselves equally into the four sequences of conditions, however, so that there was no way of eliminating the effect of practice in the comparison of individual differences. Even

if this were possible, it is very improbable that an individual score would mean a great deal since such a small sample of each subject's performance was used. Only the group averages are of significance.

This experiment indicates, then, that there is a certain amount of muscular tonus which, when induced in the subject, will cause facilitation of the learning. This degree of tension is somewhere in the neighborhood of one-half the individual's maximum, when tested in the manner used in this experiment. Lesser or greater amounts of induced muscular tension gave little or no facilitation, but this result was not statistically reliable.

EXPERIMENT II

Muscular Tension and Retroactive Interference

Problem.—The evidence from the previous experiment has shown that a certain kind and amount of induced muscular tension results in an increase in the efficiency of learning. The next question to be considered is whether material learned under these conditions of induced tonus is as well integrated, *i.e.*, as resistant to disrupting influences, as material learned under 'normal' conditions. (This does not follow from the demonstrated fact that induced tension facilitates the rate of learning.) Specifically, the purpose of this experiment is to test the degree to which material learned under induced tension is susceptible to retroactive interference, as compared with material learned without induced muscular tension. Retroactive interference was produced by introducing an interpolated list between the learning and recall of the original list.

Apparatus.—The tonus was induced in the same manner as that used in Experiment I, the amount of weight used being ten pounds per hand for the men and six pounds per hand for the women. This is approximately the optimum amount as determined by the first experiment.

The material learned consisted of six lists of fifteen, common, four-letter words.

Subjects.—As in the first experiment forty graduate and undergraduate students in psychology served as subjects. Approximately half of these subjects had already served in the previous experiment.

Procedure.—The conditions of the experiment were as shown in Table IV.

In the conditions where interpolated learning was done, this followed immediately upon the completion of the original learning. There was a twenty-four hour interval

between learning and relearning in each case. The conditions and lists used under each condition were varied systematically to counterbalance the effect of practice and possible inequality in the associative value of the lists of words.

TABLE IV
CONDITIONS OF WORK FOR EXPERIMENT II

Day	Original Learning	Interposed Learning	Recall and Relearning
First.....	Normal	Normal	Normal
Second.....	Tension	Normal	Normal
Third.....	Tension	None interpolated	Normal
Fourth.....	Normal	None interpolated	Normal

The directions to the subjects were: This is an experiment in learning. I have typed a list of fifteen, common, four-letter words and placed them on this drum. The drum revolves intermittently, so that each word appears in the window for two seconds. I want you to memorize this list of words. Learn all that you can on the first revolution of the drum and when the XX's appear, you are to say the first word. When the first word appears, say the second word and so on through the list. Each word is to act as the stimulus for you to say the following word. The word must be spoken before it appears in the window to be counted. The trials will continue until you are successful in correctly naming all the words on one revolution of the drum. Now, are you ready?

If the condition called for induced tension, the subject was told, "While you are learning, I want you to support the weights with both hands, like this." The experimenter would demonstrate the method of holding the weights, then, with the right hand since he was seated at the left of the subject.

If interpolated learning was required, the windows on the drum were adjusted immediately upon the completion of the original learning and the subject was told, "Now I would like to have you learn another list without the use of the weights." The subjects were not informed before this of the fact that two lists were to be learned on that particular day.

Just before the subject left he was admonished as follows, You are not to think of the words on this list (or these lists, as the case might be) between now and tomorrow. If you find that they are running through your mind, actively repress them by thinking of something else.

At the time of recall the instructions to the subjects were: "I want you to recall the list (or the first list) of words which you learned yesterday. Name all of them that you can on the first trial and then relearn them. You are not to use the weights. Ready?"

Results.—The learning scores under the two conditions confirm the results of the first experiment. The average number of trials to learn are shown in Table VII. It will be seen that in both cases learning was more efficient under the tension condition. The average number of trials

required to learn under the normal condition (with and without interpolation) was 14.9 ± 0.63 and for tension, 13.3 ± 0.51 . This is only a difference of 1.6 ± 0.81 . One reason for this small amount of difference undoubtedly is the fact that the same amount of weight was used for all the subjects and this was too great for some individuals and not large enough for others.

It is easy to understand the size of the P.E.'s when one remembers that there was no preliminary practice given to the subjects during this experiment. The counter-balanced order was relied upon to eliminate the effect of practice upon the averages. Since there was a great deal of practice improvement during the experiment (some of the subjects cutting the number of trials required to learn down to one-third of the first day's record) this introduced a large degree of variation in the figures and was naturally reflected in the corresponding size of the P.E.'s.

In another study by Bills and Stauffacher (2), in which the mental work was the solution of 'Detectograms' (miniature mystery stories) and the tonus was induced in the same way and in approximately the same amounts, it was found that the good performers, as measured by both the time and error criteria, were made less efficient by the introduction of tonus and the poor performers were facilitated in their work.

It was rather difficult to analyze the data of the present experiment in the same manner since there was a great deal of practice effect during the course of the learning. The counter-balanced order would take care of this for the group but it is difficult to appraise an individual's score under the two conditions. The best way to make this analysis seemed to be to take an average of the learning scores of all the subjects who learned under tension on each day; then to compute the mean of these averages; and finally, to compare this mean with the mean learning score under the normal condition after it had been computed in the same manner. Fourteen subjects were selected as good learners on the basis of the total trials to learn all the original learning lists, and fourteen poor learners were selected on the same basis. The

average number of trials to learn as determined by the method just described is shown in Table V.

The only significant effect of tension was in the case of the poor learners who were able to learn in eight trials less during induced tension. This means that only fourteen of the forty subjects were actually facilitated in their learning by the induction of the tension.

There are several possible explanations for this fact. It is true that most of the good learners were those who had served as subjects in other learning experiments and thus might be called 'practiced' subjects. Since this previous practice in learning had taken place under the so-called normal condition, the induction of tension was a distracting change in the condition of the learning for these subjects.

TABLE V
COMPARISON OF GOOD AND POOR LEARNERS UNDER NORMAL AND
TENSION CONDITIONS (TRIALS TO LEARN)

	Normal	Tension	Difference
Good performers (14).....	19.5	20.9	1.4 (N)
Poor performers (14).....	40.5	32.6	7.9 (T)
All others (12).....	29.2	27.0	2.2 (T)

Another explanation might be found in the level of tonus maintained under the normal condition. These good performers were working at a high degree of efficiency. Since efficiency in mental work is correlated with a certain degree of muscular tonus, the induced tension may have placed these subjects at a level of muscular tonicity which exceeded the facilitating amount and caused a corresponding fall in the efficiency of the learning.

Another possible explanation of this phenomenon might be suggested. Perhaps the good subjects are those who work up to the limit of their ability and the poor learners, those who do not work up to the limit of their possibilities. The tension may then be a stimulus which operates in such a manner as to make those subjects work at a higher level of efficiency. Induced tension would then be effective only

with those subjects who are working below the level of their highest potential efficiency.

These data were further analysed by dividing the subjects into two groups: one, those who had had no previous practice in learning by the anticipation method, and the other, those who had had such practice. The results of an analysis made by the same method as that used in comparing the good and the poor performers, in average number of trials to learn are as shown in Table VI.

TABLE VI
COMPARISON OF PRACTICED AND NON-PRACTICED SUBJECTS UNDER NORMAL AND TENSION CONDITIONS (TRIALS TO LEARN)

	Number of Subjects	Normal	Tension	Difference
Non-practiced Subjects				
Good learners.....	8	20.2	19.4	.8 (T)
Poor learners.....	8	50.1	32.6	17.5 (T)
All others.....	8	32.1	27.7	4.4 (T)
Practiced Subjects				
Good learners.....	6	18.7	22.3	3.6 (N)
Poor learners.....	6	36.9	32.6	4.3 (T)
All others.....	4	26.3	26.2	.1 (N)

This table shows that the principal effect of tension occurred in the case of the eight, unpracticed, poor learners. This effect was almost entirely concealed when the total group of forty subjects was considered.

The degree to which material learned under induced tension is susceptible to retroactive interference as compared with material learned without induced tension is shown in a comparison of the recall, savings and relearning scores.

The recall scores are given in Table VII in terms of the average numbers of words correctly anticipated during the first relearning trial. The amount of decrement in recall of material learned under the normal condition which results from the interpolated work is $5.98 - 4.33$ or 1.65 . The amount of decrement in recall of material learned under the

induced tension condition which results from similar interpolated learning is $5.63 - 4.48$ or 1.15 . There is, then, .5 or 30 percent less decrement in recall after the interpolation when tension is induced at the time of the original learning.

TABLE VII
THE EFFECT OF INDUCED TENSION UPON THE REINSTATEMENT OF
MATERIAL LEARNED UNDER 'NORMAL' TENSION

	Without Interpolation			With Interpolation		
	Learning	Recall	Relearning	Learning	Recall	Relearning
Normal...	14.2 ± 0.75	5.98 ± 0.38	5.53 ± 0.30	15.5 ± 0.78	4.33 ± 0.36	6.4 ± 0.25
Tension...	13.4 ± 0.52	5.63 ± 0.37	4.75 ± 0.27	13.2 ± 0.66	4.48 ± 0.31	5.1 ± 0.29
Difference.	$.8 \pm 0.91$	$.35 \pm 0.53$	$.78 \pm 0.41$	2.3 ± 1.02	$.15 \pm 0.48$	1.3 ± 0.39

The savings scores, using the formula

$$S = 1 - \frac{\text{trials to relearn}}{\text{trials to learn}} \times 100,$$

are as follows:

	Normal	Tension
Without interpolation.....	61.2%	64.5%
With interpolation.....	58.7%	61.8%
Difference.....	2.5%	2.7%

Thus according to the savings scores there is practically no difference between the two conditions. One would not expect to find a difference here, since the same subjects and lists were used under the two conditions, unless the induced tension produced more resistance to retroactive interference than it did facilitation of learning. Since the tension condition did facilitate learning and there was no difference in savings scores, one is led to the conclusion that the resistance to retroactive interference was not increased more than the efficiency of learning was facilitated by the induced tension.

The difference between the two conditions is more evident, however, when the relearning scores are compared. Relearning scores are determined by two factors: the amount of retention and the learning ability of the subject. Since the same lists were used under both conditions, and the

subjects were identical, relearning scores, in this case, are a measure only of the amount of retention.

The difference between the normal and the tension conditions when there was no interpolated learning is $.78 \pm 0.41$ and when there was interpolated learning the difference becomes 1.3 ± 0.39 . This difference is made more striking when the correlations between the learning and relearning of the forty subjects under the two conditions are taken into consideration. The rank order correlations, using the formula

$$\rho = 1 - \frac{6\sum d^2}{n(n^2 - 1)}, \text{ are as follows:}$$

Between Learning under Normal and Tension (No Interpolation).....	.362
Between Relearning under Normal and Tension (No Interpolation).....	.123
Between Learning under Normal and Tension (With Interpolation).....	.409
Between Relearning under Normal and Tension (With Interpolation).....	.348

The differences between learning and relearning under the two conditions and their P.E.'s with the correlations taken into consideration by use of the formula

$$PE_d = \sqrt{(PE_1)^2 + (PE_2)^2 - 2\rho PE_1 \cdot PE_2}$$

are as follows:

Without Interpolation		With Interpolation	
Learning	Relearning	Learning	Relearning
$.8 \pm 0.74$	$.78 \pm 0.38$	2.3 ± 0.79	1.3 ± 0.31

It will be noticed that whereas the difference in relearning was $.78 \pm 0.38$ (critical ratio of 2) when there was no interpolated learning, the difference in relearning with interpolation became 1.3 ± 0.31 (critical ratio of 4). This is certainly a significant difference in favor of the tension condition.

An attempt was made to compare the retroactive effects in the case of the good and poor performers by the use of the same analysis which was used for learning. No differentiation could be made on this basis.

This experiment has indicated that there is a slight tendency for the resistance to retroactive interference to be increased by the induction of a certain degree of tension during the original learning. This degree of tension was approximately that amount which had proved to facilitate

learning. There is also an indication that poor learners benefit from the induced muscular tension in terms of increased efficiency in learning whereas the good learners are inhibited. Among the poor learners, those who had had no previous practice in the anticipation method of learning seemed to benefit much more than the practiced poor learners.

EXPERIMENT III

Muscular Tension and Relearning

Problem.—There are many factors which complicate the picture and obscure the effect of muscular tonus on the mental processes. The first two experiments have demonstrated a few of those. The effect of induced muscular tension on learning depends upon its degree, the level of efficiency of the subject and his experience with the task involved. The second experiment also indicated that learning is ‘stamped in’ in a more stable fashion if that learning has been accomplished under a certain amount of induced muscular tension. The problem to be dealt with in this experiment is the determination of the effect of induced muscular tension introduced during recall and relearning upon the efficiency of reinstatement.

Apparatus and Subjects.—The tonus was induced in the same manner as in Experiment II. The material used was also of the same type, two different lists of fifteen, common, four-letter words being used in this case. As in the other experiments, forty graduate and under-graduate students in psychology served as subjects.

Procedure.—The conditions of the experiment were as follows:

Learning	Relearning
Normal.	Normal
Normal.	Tonus

The position of the induced tension during relearning was varied so that any differences due to practice effect or to the difficulty of the lists were counter-balanced.

The instructions given to the subjects before and after the learning were the same as in the previous experiment, as were the instructions at the time of relearning. The interval between learning and relearning was twenty-four hours.

Results.—The results of this experiment are given in Table VIII. Condition I is that condition in which relearning was done under normal tension and Condition II is the condition in which relearning was done under induced tension.

It will be seen that none of the differences are significant. The difference between trials taken to relearn and the number of words recalled on the first trial is, in both cases, about equal to its probable error. The savings scores were also computed and they show practically no difference between the two conditions. The savings score for Condition I is 74.5 percent and for Condition II, 74.2 percent.

TABLE VIII
THE EFFECT OF TENSION INDUCED DURING REINSTATEMENT
UPON THE EFFICIENCY OF REINSTATEMENT

	Learning (Trials)	Recall (Words Named)	Relearning (Trials)
Condition I.....	17.8±0.80	8.23±0.31	4.6±0.34
Condition II.....	19.9±1.71	8.78±0.35	5.1±0.69
Difference.....	2.1±1.81	.55±0.47	.5±0.77

It will be noticed, however, that in Condition II the induction of tension during reinstatement caused the recall and relearning to be done under a condition which was not similar to that under which it was learned. There are, then, two factors which influence the efficiency of the reinstatement under Condition II: the induced tension, and the change in the condition. If reinstatement under Condition II had proven to be more efficient than under the other (normal) condition, in spite of the detrimental effect of the change of conditions, then the results would have been unambiguous. As it was, however, another experiment seemed to be indicated, the conditions of which would be as follows:

	Learning	Relearning
Condition I.....	Tension	Normal
Condition II.....	Tension	Tension

This experiment was conducted using twenty subjects and the same apparatus and procedure as that used in the previous experiment, except for the change in the conditions which has been described. The results are given in Table IX.

It will be seen that there is no significant difference between the recall or the relearning under the two conditions.

TABLE IX

THE EFFECT OF TENSION INDUCED DURING REINSTATEMENT UPON THE EFFICIENCY OF REINSTATEMENT OF MATERIAL LEARNED UNDER TENSION

	Learning (Trials)	Recall (Words Named)	Relearning (Trials)
Condition I.....	17.9±2.57	5.9 ±0.72	5.61±0.42
Condition II.....	18.1±2.84	6.15±0.49	5.9 ±0.56
Difference.....	.2±3.84	.25±0.87	.29±0.70

An analysis was made of the effect of the tension condition upon the recall and relearning of the good and poor learners, in the same way in which the analysis of learning was made in Experiment II. The results are shown in Table X. It

TABLE X

COMPARISON OF RECALL AND RELEARNING OF GOOD AND POOR LEARNERS UNDER NORMAL AND TENSION CONDITIONS OF REINSTATEMENT

	No. of Subjects	Normal	Tension	Difference
Recall				
Poor learners.....	10	5.5	6.2	.7 (T)
Good learners.....	10	6.3	6.1	.2 (N)
Relearning				
Poor learners.....	10	6.9	6.3	.6 (T)
Good learners.....	10	4.5	5.5	1.0 (N)

will be seen that there is an indication that poor learners were facilitated in both recall and relearning by the induction of the tension, and that the good learners were inhibited. The most striking result occurs in the case of the relearning of the good learners when the inhibitory effect of the tension is over 20 percent.

This experiment, then, shows no over-all effect in recall or relearning from the induction of tension at the time of reinstatement. There is an indication, however, that poor learners are facilitated and good learners inhibited both in recall and relearning by the tension condition. In this connection, it will be remembered that Experiment II showed

that tension induced during learning facilitated the learning of the poor learners, but inhibited the learning efficiency of the good learners.

CONCLUSIONS

1. This study corroborates previous investigations in finding that a certain amount of induced muscular tension facilitates learning. (Experiments I and II.)

2. Degrees of induced muscular tension which are smaller or greater than the facilitating amount give little or no facilitation of learning. (Experiment I.)

3. Although there is a slight indication that material learned under a degree of induced muscular tension which is facilitative to learning is stamped-in more firmly and consequently there is less decrement in recall and relearning after interpolated learning than is present when the original learning takes place under the 'normal' conditions of tension, these results are not reliable and no final conclusion can be drawn from them. (Experiment II.)

4. Poor learners benefit from induced muscular tension in terms of increased efficiency in learning, whereas good learners do not. (Experiment II.)

5. Among the poor learners, those who have had no previous practice in the anticipation method of learning benefit much more than the practiced poor performers. (Experiment II.)

6. Recall and relearning efficiency are not significantly affected by the introduction of induced muscular tension during the reinstatement when the whole group of subjects is considered. (Experiment III.)

7. There is an indication, however, that poor learners may be facilitated and good learners inhibited in both recall and relearning by the induction of tension during reinstatement. (Experiment III.)

8. These experiments have indicated that there is a facilitating effect of induced muscular tension but that it is modified by many factors such as the amount of tension used, the length of the task, the level of performance of the subject,

and his past experience (practice in the task). It is difficult to demonstrate the effect of tonus with reliability unless these factors are controlled.

DISCUSSION AND INTERPRETATION

Muscular tension does not produce its effect upon the efficiency of mental performance in the same way that many so-called 'distractors' do, *i.e.*, by drawing the subject's attention away from the task so that an increase in effort (which actually results in facilitation of the performance) is necessary to overcome this effect. Morgan (12) found that when a sound distraction was long continued it gradually ceased to exert a distracting influence. He reports that there was an increased tension throughout the period of the distraction, however, even after the distraction had become ineffective in causing a work decrement. Perhaps the presence of the tension is responsible for the increased efficiency which Morgan reported to have resulted from the distraction. Bills (1) found that the increase in efficiency gained by the use of tension was enhanced with practice. It is evident that the effect of the tension is not like that of a distracting sound since in that case it would gradually become less effective with continued practice.

Ford (6), working with a problem solving situation during severe sound distraction, found that as 'automatization' became more and more complete tonus as measured by a pressure pencil became progressively less. Instead of the tonus acting as a distractor, again it seemed to be one of the factors which was effective in overcoming the effect of the distraction exerted by other influences.

The theory of G. L. Freeman (8) offers a more plausible explanation of the way in which muscular tonus operates in producing an effect upon the mental processes. He assumes that cortical centers involved in mental work have high thresholds. When these thresholds are lowered the centers will react to stimuli which would otherwise be inadequate. This is accomplished by the spread of proprioceptive impulses which travel to the cortex from lower centers, especially those

involved in muscular contraction. If this proprioceptive stimulation falls below a minimum level, cortical neurones become incapable of adequate response. The work of Jacobson on relaxation substantiates the theory at this point. Above a certain maximum, tension becomes an inhibitor of precise neural integration. The facilitative effect is only within limits, which vary presumptively from individual to individual. The establishment of a facilitative level of tension in Experiment I confirms this portion of the theory.

Experiment I showed that there is a certain amount of tonus which, when induced in the subject, will cause a facilitation of the learning. The lesser or greater amounts of induced muscular tension which were used gave little or no facilitation. The continuous line in Fig. 1 shows these

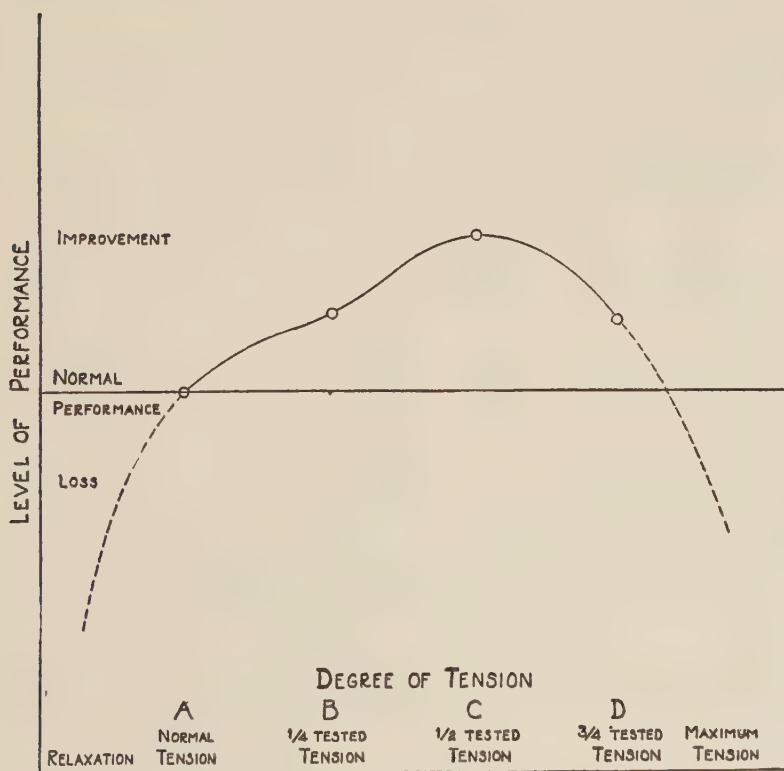


FIG. 1. Relation between degree of tension and levels of performance.

results. It will be noticed that the levels of performance of Conditions *B* and *D* were placed approximately midway between the level of performance given by Condition *C* and that of the normal condition. These were the actual findings but the differences between the normal condition and Conditions *B* and *D* were only about two times their P.E. Because of the questionable reliability of these differences, the statement has been made that they gave "little or no" facilitation.

The studies of Jacobson indicate that if a subject is relaxed to a much greater degree than normal, mental work is possible only at a much lower level of efficiency than under normal conditions. Freeman (8) showed that a high degree of induced tension will cause a decrement in the efficiency of mental work. The results found by these two investigators are indicated in the figure by the dotted lines.

Since there is a certain degree of tonus for the highest efficiency of mental work, one would expect that if a subject were working at a very high degree of efficiency, a corresponding high degree of tonus would already be present and that any increase in muscular tonicity would prove to be detrimental to the efficiency of mental work. This is what one actually finds. Several studies, such as that of Stroud (14) with stylus maze learning, have shown that with increased efficiency of learning there is an incidental increase in muscle tension. Bills and Stauffacher (2), working on a problem solving situation, found that the most efficient performers worked at a higher level under the 'normal' condition and the poorer performers were more efficient during the induced tension condition. This result is confirmed by the findings of Experiment II on learning. One is led to the conclusion that good performers were already working at a very high level of efficiency (correlated with a certain degree of muscular tonicity) and that the increased tonus placed their level of muscle tonus over the facilitating degree and therefore caused a decreased efficiency of performance.

This is one of the factors which are probably responsible

for the large amount of individual differences which appear in many studies of the effect of varying amounts of muscle tension. The neglect of such factors is illustrated by the study of the effect of varying amounts of muscular tension which was reported by Block (3). She found that 22 pounds tension induced in both arms was optimal for half of her eight subjects when speed was the criterion of efficiency and for three-quarters of her subjects when accuracy was the criterion. It is surprising that these percentages were as large as they were since one would expect the facilitating degree of tension to vary with the individual. In other words, a degree of induced tonus which would be facilitative for one individual might be actually detrimental for another. Then in any study of the effect of induced muscular tension in which a fixed amount of tension was used, one would expect to find subjects who were not facilitated by that amount of tension unless careful selection of the subjects were practiced.

The results of this study tend to confirm Washburn's 'Motor Theory of Consciousness' which asserts that the motor processes are not only accompaniments of consciousness but that they play a direct causal rôle in consciousness. Muscular processes do affect the efficiency of mental work. The subject reacts as a whole and his mental, sensory and motor processes can only be separated ideationally, since each influences the others and is in turn influenced by them.

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